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Estimation of sex from index and ring finger in a North Indian population

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ABSTRACT

Estimation of sex is an important parameter in the examination of unknown dismembered and commingled remains. The present study explores the possibility of estimation of sex from length of index and ring finger and the index and ring finger ratio in 140 individuals (70 boys and 70 girls) from North India. Index finger length (IFL) and ring finger length (RFL) of the participants were measured following standard procedures and landmarks. Sex differentiation in the present study was based on sectioning point analysis. The 'sectioning point' for the IFL, RFL and the index and the ring finger ratio was estimated from the average of the mean of male and female values. Binary logistic regression (BLR) analysis was employed to derive a predicting equation for estimation of sex. The results of the present study indicate that significant sex differences exist in the IFL and RFL and index and ring finger ratio. Among finger lengths, RFL is a better predictor of sex than IFL. It is further concluded that the index and ring finger length is of limited utility in estimation of sex in forensic casework and should be employed only in cases when no other means of sexing are available. The study suggests that the index and ring finger ratio should not be employed in estimation of sex in forensic casework due to considerable overlap in male and female values.
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1. Introduction

Forensic anthropology involves the identification of unknown skeletal and commingled remains in a legal context. The process of identification focuses mainly on establishing the biological profile by estimating the sex, age, stature, and ancestry.[1] Identification of commingled and dismembered remains has always been a challenge for forensic anthropologists.[2] The need of identification of commingled and dismembered remains arises in cases of mass disasters and in certain cases of homicide where dead bodies are dismembered into parts to conceal the identity of the victim. Establishing the identity of the deceased is of utmost importance for the investigators to establish a crime in cases where the bodies are severely mutilated.

Estimation of sex along with other parameters of identification like stature, age and ancestry[3] is one of the foremost criteria in establishing the biological profile of an individual. Various researchers have conducted studies on estimation of sex from anthropometric measurements of the upper and lower limbs,[4–10] long bones of the extremities,[11–22] small bones of hands and feet[23–25] and from other bones of the body.[26–32] Significance of hand in identification based on its morphometric and skeletal analysis has been reported in the recent past.[33–40] Systematic studies on estimation of sex from different dimensions of the hand have been reported in different populations.[2,10,41–43] Recent studies carried out on the estimation of sex from index and ring finger ratio in adult and sub-adult populations from South India[44–46] observed that statistically significant sex differences exist in the ratio. Similar studies are not reported in any North Indian population groups. Moreover, the sexual dimorphism of the length of index and ring finger has not been explored earlier. In the case of still growing individuals, age is a critical identifying variable. Age of epiphyseal

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Table 1
Age and sex distribution of the study sample.

Age (years)	14	15	16	17	18	Mean (S.D.)
Male ($n = 70$)	09	18	14	19	10	16.04 (1.28)
Female ($n = 70$)	13	24	19	14	00	15.49 (1.02)
Total ($n = 140$)	22	42	33	33	10	15.81 (1.33)

S.D. – standard deviation.

fusion varies in males and females; the epiphyseal union occurring earlier in females than males. Correct prediction of sex in sub-adult populations can narrow down the pool of possible victim matches directly as well as by providing a distinct advantage in estimation of age more precisely based on the predicted sex. In the present study, an attempt is made to establish standards for estimation of sex from index and ring finger length in a sub-adult North Indian population.

2. Material and methods

The present study was conducted on 140 individuals (70 boys and 70 girls) aged between 14 and 18 years. Age and sex distribution of the study participants is shown in Table 1. The sample was taken from Government Senior Secondary School, Naggar and Government High School, Nathan in District Kullu of Himachal Pradesh State in North India (Fig. 1). Rajputs are one of the major populations of North India. All the study participants included in the study were Rajputs – a major endogamous group in North India. Only right handed individuals were included in the study so that the handedness may not affect the standards of the data. It is a well-known fact that the handedness (whether left or right) can significantly affect the dimensions of the dominant side of the body. Previous studies have reported measurable differences in the different measurements of the left and right hands.[33,40] Individuals with any disease or deformity of fingers and hand were not included in the study.

2.1. Finger length measurements and techniques

Two anthropometric measurements, Index finger length (IFL) and ring finger length (RFL) were measured on the study participants using standard procedures and landmarks following Manning et al.[47] The IFL was measured from the mid point of the proximal crease at the base of the index finger to the tip of the index finger while the RFL was measured from the mid point of the proximal crease at the base of the ring finger to the tip of the ring finger. The finger measurements were taken independently on left and right sides of the participants using standard sliding calipers in centimeters to the nearest millimeter. The landmarks for taking measurements on fingers are shown in Fig. 2. Index and ring finger ratio was derived by dividing IFL by RFL in each individual. While collecting the data, the instruments were regularly checked for their accuracy. The finger length measurements were taken by a trained physical anthropologist (NA). Before taking up the present research, finger lengths (IFL, RFL) were measured in 15 participants

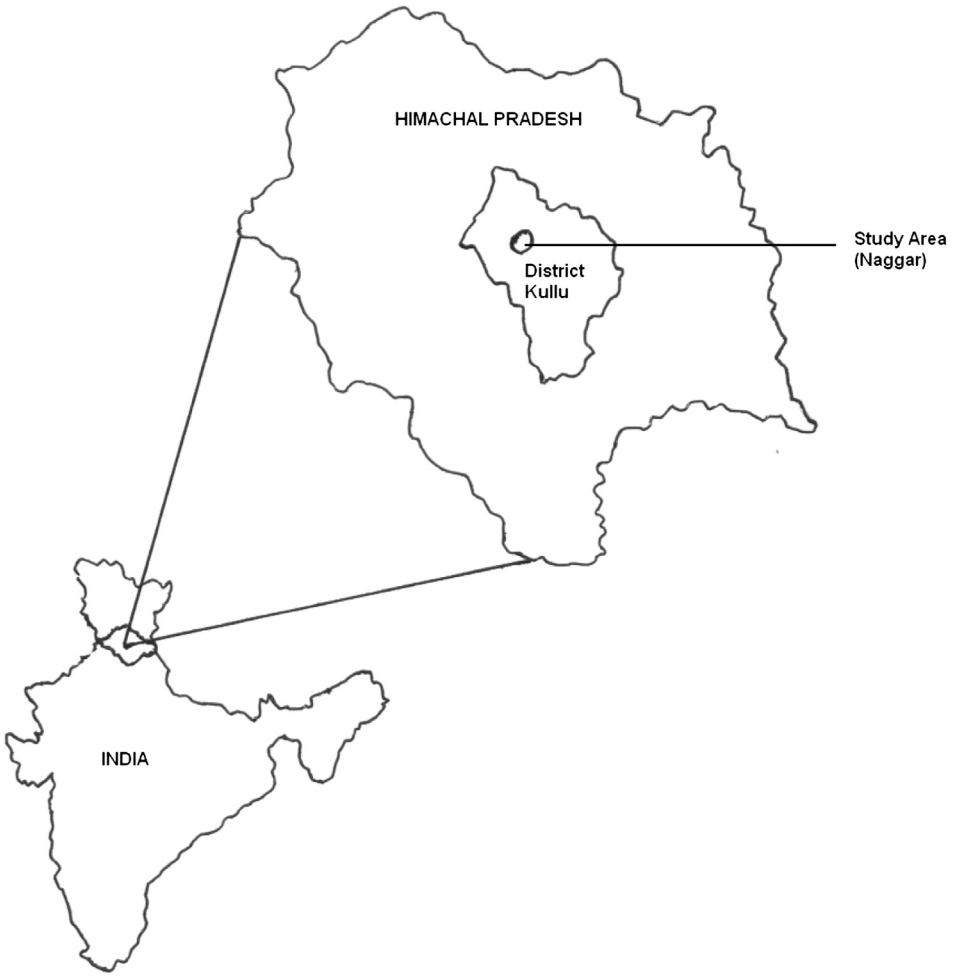

Fig. 1. Map of the study area in India (Not to scale).

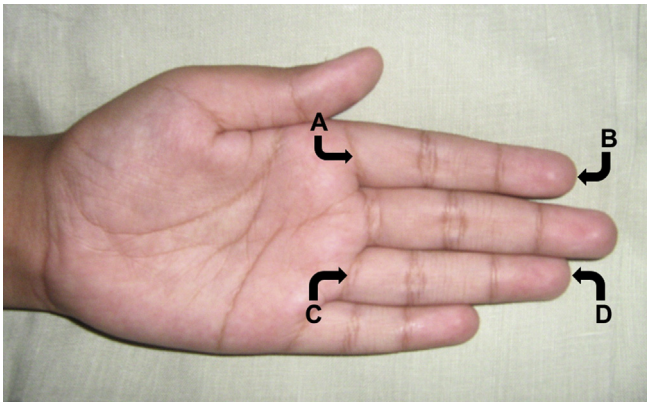

Fig. 2. Landmarks on the hand for the measurement of index and ring finger length (A to B = IFL, C to D = RFL).

by two observers (NA and KK) and tested for inter-observer error in measurements. NA measured the IFL and RFL again after a couple of days to find the intra-observer error in measurements. Both inter-observer and intra-observer error were estimated using the paired *t*-test. No significant inter-observer error ($t = 0.695$, $p = 0.499$ for 'IFL', and $t = -0.367$, $p = 0.719$ for 'RFL') and intra-observer error ($t = -1.871$, $p = 0.082$ for 'IFL', and $t = -0.564$, $p = 0.582$ for 'RFL') were observed. The results indicate that the measurements are reproducible without a significant measurement error.

2.2. Statistical analysis

The data obtained was analyzed statistically using SPSS computer software (SPSS, Inc., Chicago, IL, USA) version 11.0. Sex differences in the IFL, RFL and the index and the ring finger ratio were analyzed using the Student's *t*-test. Bilateral differences in measurements are analyzed using the Paired *t*-test. Statistical significance (*p*-value) was defined as $\alpha = 0.05$. Sex differentiation in the present study was based on sectioning point analysis. The 'sectioning point' for the IFL, RFL and the index and the ring finger ratio was estimated from the average of the mean of male and female values.[48] Accuracy of sectioning point analysis was tested on the study sample itself.

$$\text{Sectioning Point} = \frac{(\text{Mean male value} + \text{Mean female value})}{2}$$

Binary logistic regression (BLR) analysis was employed to derive a predicting equation for estimation of sex from index and ring finger length. BLR provides a probability of sex estimation based on the maximum likelihood approach. Receiver Operating Curve (ROC) was applied on the predicting probability obtained from BLR analysis. Area under the curve was considered as the predictive accuracy of IFL and RFL taken together in the estimation of sex.

3. Results

Index and ring finger lengths were found to be significantly larger ($p < 0.001$) in boys than girls in both right and left hands (Table 2). The ring finger was longer than the index finger in boys and girls. The ring finger showed a relatively larger difference in length between boys and girls than the index finger. The difference between ring finger length and index finger length (RFL − IFL) was thus, larger in boys than girls on right and left sides (Table 2). The descriptive statistics of index and ring finger ratio for boys and girls are shown in Table 2. Index and ring finger ratio was found to be significantly larger in girls than boys on the right and the left sides.

Age wise changes in the index and ring finger lengths are explored to study the growth pattern in finger lengths among the sub-adult participants included in the study (Table 3). Sex differences observed in the index and ring finger length were statistically significant all through during the age of 15, 16 and 17 years except for LIFL. During 14 years of age, statistically significant sex differences were observed only for the LRFL. Index and ring finger ratio shows statistically significant sex differences only for 15 years age.

No significant right–left differences were observed in the length of index and ring fingers in boys. Among girls, index finger was significantly larger on the left side ($p = 0.038$) while ring finger length did not show any significant right–left differences. Index and ring finger ratio did not show any significant side differences among boys and girls (Table 4).

The sectioning points derived for the index finger length, ring finger length, and index and ring finger ratio are shown in Table 5. The sectioning points derived in the study were applied on the study sample itself to find the predictive accuracy of index finger length, ring finger length and index and ring finger ratio in estimation of sex. It is evident that the Sectioning points derived for index and ring finger length estimate sex with an accuracy ranging between 70.7% (LIFL) and 75.0 (LRFL). Mean correct prediction percentage (CPP) was higher for the ring finger length than the index finger length in both hands. CPP for the index and ring finger ratio was 55.7% and 59.3% for the right and left hand respectively (Table 5).

Frequency distribution of the index finger and ring finger lengths among boys and girls on right and left sides is depicted in Fig. 3. The figure shows the extent and range of overlap in male and female values for the index finger and ring finger lengths in the right and left hands. The index and ring finger ratio showed a considerable overlap in the right and left hand among boys and girls (Fig. 4). Predicting equations derived for the estimation of sex

Table 2
Descriptive statistics: index finger length, ring finger length and index and ring finger ratio.

	Male ($n = 70$)			Female ($n = 70$)			*t*-value	*p*-value
	Range	Mean	S.D.	Range	Mean	S.D.		
RIFL	5.6–8.2	6.95	0.48	5.8–7.5	6.53	0.39	5.677	<0.001
RRFL	5.8–8.3	7.23	0.47	5.9–7.9	6.73	0.41	6.771	<0.001
LIFL	5.5–8.2	6.97	0.47	5.8–7.6	6.55	0.40	5.687	<0.001
LRFL	5.8–8.4	7.26	0.48	5.9–7.9	6.73	0.41	7.041	<0.001
RR	0.90–1.00	0.96	0.02	0.91–1.03	0.97	0.03	−2.401	0.018
LR	0.90–1.00	0.96	0.02	0.91–1.03	0.97	0.03	−3.071	0.003

RIFL – ring index finger length, RRFL – right ring finger length, LIFL – left index finger length, LRFL – left ring finger length, RR – right index and ring finger ratio, LR – left index and ring finger ratio, S.D. – standard deviation.

Table 3
Index finger length, ring finger length and index and ring finger ratio in different ages.

Age	14 years		15 years		16 years		17 years		18 years	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
RIFL	6.67	6.38	6.93*	6.52*	6.93*	6.62*	6.95*	6.56*	7.26	–
RRFL	6.97	6.62	7.25*	6.65*	7.21*	6.84*	7.23*	6.83*	7.49	–
LIFL	6.64	6.39	6.90*	6.55*	6.89	6.62	7.07*	6.61*	7.29	–
LRFL	7.02*	6.62*	7.21*	6.67*	7.19*	6.82*	7.35*	6.82*	7.51	–
RR	0.956	0.963	0.955*	0.982*	0.962	0.968	0.962	0.960	0.969	–
LR	0.955	0.965	0.959*	0.982*	0.959	0.971	0.963	0.969	0.971	–

♂ – male, ♀ – female, RIFL – ring index finger length, RRFL – right ring finger length, LIFL – left index finger length, LRFL – left ring finger length, RR – right index and ring finger ratio, LR – left index and ring finger ratio.
*p-value <0.05 for male–female differences.

from index and ring finger length are shown in Table 6. It is evident from the Receiver Operating Curve (ROC) analysis applied on the predicting probability obtained from BLR analysis that IFL and RFL together have a potential of discriminating sex in the right (80.7%) and left hands (82.2%). The same is depicted in Fig. 5.

4. Discussion

Morphologically, sex differences have been reported in the length of the fingers of the hand.[49,50] In the present investigation, male fingers are found to be significantly larger than females, similar to that reported in earlier studies.[44–46,50] The ring finger was found to be longer than the index finger in both males and females. Similar findings are observed in the earlier studies in adult[46] and sub-adult groups.[44,45] In the present study, the ring finger was found to have a relatively larger difference in length between males and females than the index finger; the results are similar to the earlier studies conducted by Kanchan et al.,[44] Kanchan and Kumar,[45] Kanchan et al.[46] and Lippa.[50] However, the difference between ring finger length and index finger length (RFL – IFL) reported among females in our study was larger than that reported in earlier studies.[44–46] The results of the present study seem to indicate that besides a size-based difference in the hand dimensions, there is a shape-based difference between males and females. However, the same needs to be explored in future studies utilizing more dimensions of the hand.

The growth pattern of index and ring finger through the different ages in the study group indicates that the fingers were still growing among boys and girls. Despite of a smaller sample size in each age, statistically significant sex differences were observed in the index and ring finger length all through during the age of 15, 16 and 17 years except for LIFL. Complete union of epiphysis for metacarpals and phalanges occur between 14–19 years in males and 13–17 years in females.[51]

Bilateral differences in the measurements can affect the standards derived in the study and findings obtained from one side may not be applicable to the other owing to the side differences. In the present investigation, the bilateral differences in the index and ring finger length were not found to be significant except for the right index finger length in females. Similarly, findings on bilateral differences are reported by Habib and Kamal[33] on the hand and phalanx lengths in an Egyptian population, Jasuja and Singh[40] on hand and phalanx lengths in a North Indian population, Rastogi et al.[52] on middle finger length in North and South Indians, and Krishan and Sharma[38] on hand length in a North Indian population. Rastogi et al.[37] have reported significant bilateral differences in the hand length of North and South Indians. These studies were however, conducted on adult populations.

In the past, the index and ring finger ratio has been put forward as a potential indicator of sex due to the significant sex differences in the ratio with males tending to have lower values than females. A lower index and ring finger ratio have thus, been considered "masculine" and higher ratios as "feminine".[45] This sex difference arises early in fetal development and may result from the effects of prenatal testosterone and estrogen on the relative growth rate of the 2nd and 4th digits.[53,54] The ratio of length of second digit to fourth digit is considered as one of the biometric markers that is influenced by estrogen and testosterone concentrations in utero and are determined genetically by HOX genes (homeodomain-containing homeotic genes).[55] Earlier studies have shown an association between the index and ring finger ratio and various socio-psychological traits, certain syndromes and diseased conditions, physical performance and characteristics in both the sexes such as sports performances,[56–59] sociosexuality,[60] myocardial infarction,[61] polycystic ovary syndrome,[62] schizophrenia and cerebral lateralization,[63] prostate cancer,[64] genital development, reproductive health, sexual behavior, and aggression.[65–70] Males have been reported to have lower digit ratio than females.

The present research shows statistically significant sex-differences in the index and ring finger ratio similar to that reported in the earlier studies by Kanchan et al.,[44] Kanchan and Kumar,[45] Kanchan et al.[46] These findings are also found to be similar with other studies conducted on different populations worldwide.[47,49,51,71,72] Voracek and Loibl[72] has reported a detailed scientometric analysis and bibliography of research on digit ratio during the last decade. It has been emphasized that there is a limited utility of sexual dimorphism shown by index and ring finger ratio in forensic casework and that the ratio remains a weak indicator of

Table 4
Bilateral asymmetry in finger lengths and index and ring finger ratio.

Right–left	Male (n = 70)		Female (n = 70)	
	t-value	p-value	t-value	p-value
IFL	−1.151	0.254	−2.116	0.038
RFL	−1.455	0.150	−0.125	0.901
IR ratio	0.203	0.840	−1.833	0.071

IFL – index finger length, RFL – ring finger length, IR ratio – index and ring finger ratio.

Table 5
Correct prediction percentage (CPP) based on sectioning point (mean) analysis.

Variable(s)	SP	CPP♂	CPP♀	Mean
RIFL	6.74	71.4	72.9	72.2
LIFL	6.76	71.4	70.0	70.7
RRFL	6.98	72.9	75.7	74.3
LRFL	6.99	74.3	75.7	75.0
RIR ratio	0.965	54.3	57.1	55.7
LIR ratio	0.967	58.6	60.0	59.3

SP – sectioning point, ♂ – male, ♀ – female, RIFL – right index finger length, LIFL – left index finger length, RRFL – right ring finger length, LRFL – left ring finger length, IR ratio – index and ring finger ratio.

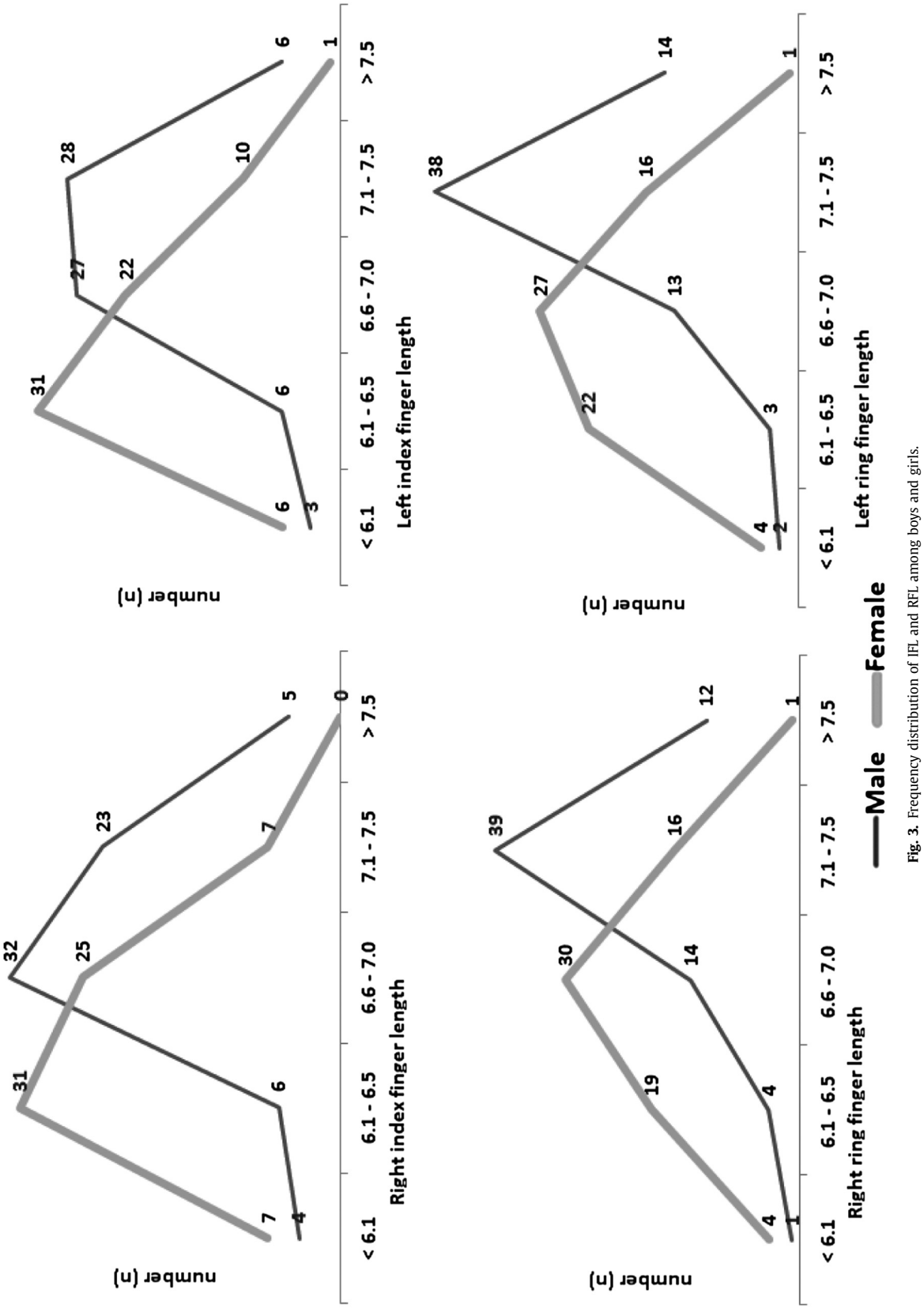

Fig. 3. Frequency distribution of IFL and RFL among boys and girls.

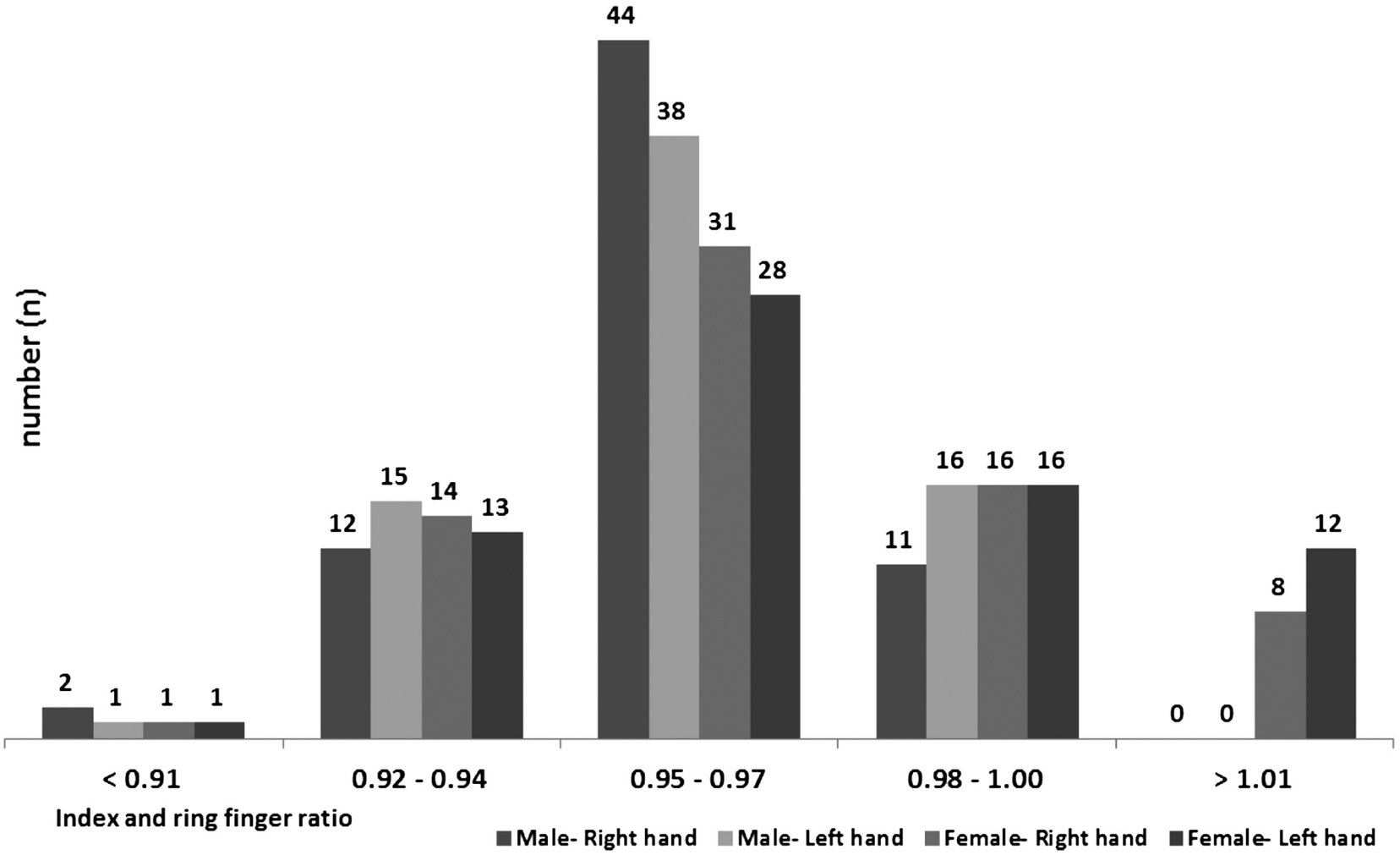

Fig. 4. Frequency distribution of index and ring finger ratio among boys and girls.

Table 6
Binary logistic regression analysis for estimation of sex from the index and ring finger length.

Variable	Regression model	Wald
RIFL	15.018 − 2.229 (RIFL*)	22.040
RRFL	18.655 − 2.672 (RRFL*)	27.133
LIFL	14.915 − 2.206 (LIFL*)	22.374
LRFL	19.017 − 2.718 (LRFL*)	28.470
RIFL, RRFL	18.208 + 1.739 (RIFL) − 4.286 (RRFL*)	RIFL-1.930, RRFL-10.883
LIFL, LRFL	18.470 + 2.243 (LIFL) − 4.806 (LRFL*)	LIFL-3.273, LRFL-13.533

RIFL − ring index finger length, RRFL − right ring finger length, LIFL − left index finger length, LRFL − left ring finger length.
*$p \leq 0.001$.

sex.[72] Voracek[73] based on a comparative analysis of earlier studies observed that the index and the ring finger-length ratio is only modestly sexually differentiated, and thus an inappropriate trait for estimation of sex. The present study sample from North India exhibits a comparatively weaker sexual dimorphism of index and ring finger ratio when compared to the studies done in South India. This can be attributed to the fact that the ratio shows significant ethnic and population variability.[74,75]

The present study observes that the finger length measurements identify the sex with greater accuracy when compared to the index and ring finger ratio. The lower predictive accuracy of index and ring finger ratio is attributed to a higher degree of overlap in the male–female values that makes it an inappropriate trait in the estimation of sex. IFL and RFL estimate sex with an accuracy

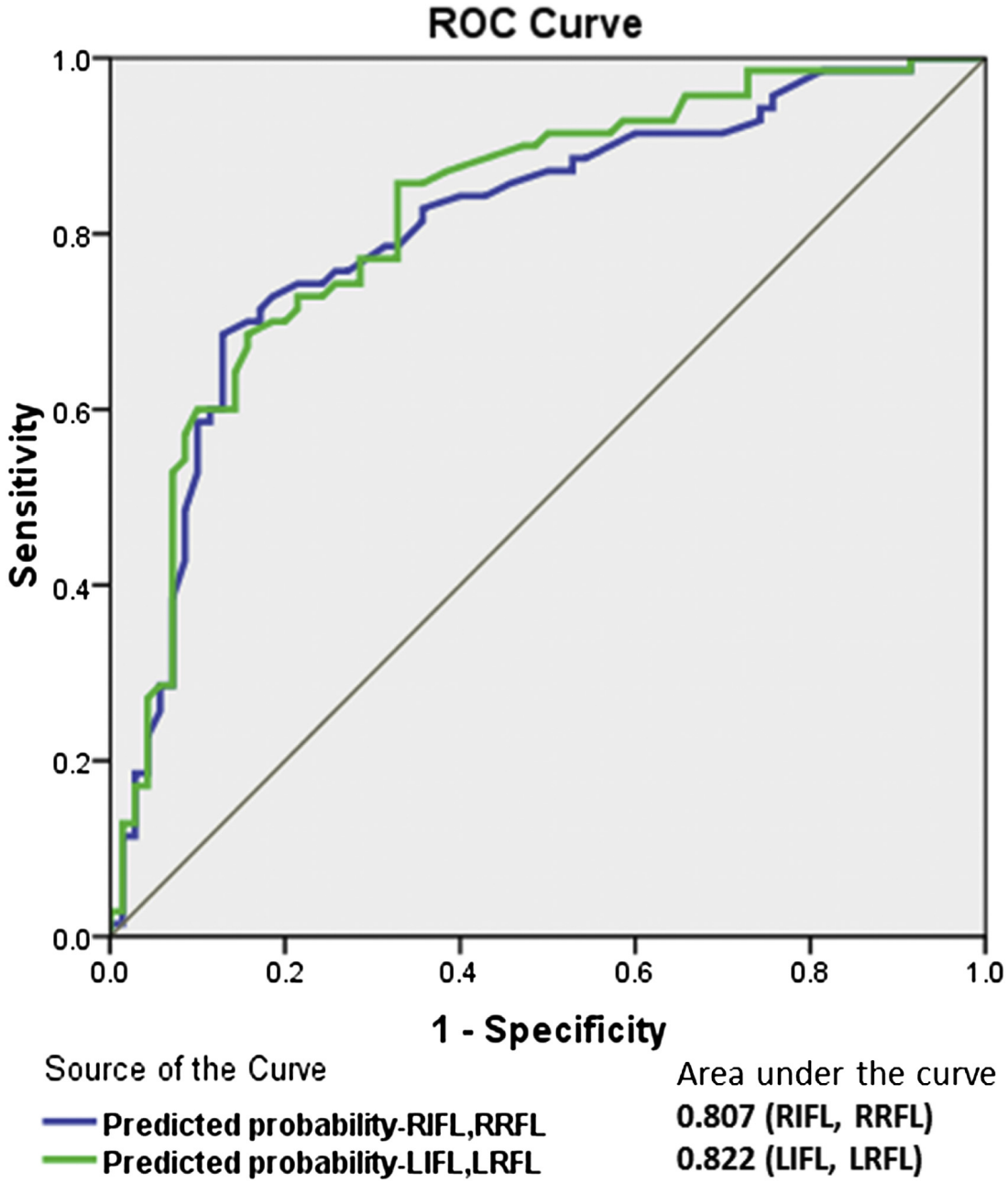

Fig. 5. ROC analysis indicating the predictive probability of IFL and RFL together in estimation of sex.

ranging between 70.7% (LIFL) and 75% (LRFL). The RFL appears to be a better predictor of sex than IFL. Accuracy of finger length in sex estimation of sex has not been reported in any earlier studies hence, the findings of the study cannot be compared per se. The sexing accuracy of finger lengths is found to be lower than that reported from morphometric analysis of hand in the earlier studies.[9,10,41] The results of our study with regard to correct prediction percentage based on sectioning point analysis may be inflated owing to the fact that the sectioning points derived in the study are applied to the same study group from which it was derived. Based on BLR and ROC analysis it is evident that the predicting potential for sexing increases when index and ring finger are taken together. LIFL and LRFL appear to be better predictors of sex than RIFL and RRFL.

5. Conclusion

The present study shows that significant sex differences exist in the length of index and ring finger and index and ring finger ratio in an endogamous North Indian population. It is observed that finger lengths are a better predictor of sex than index and ring finger ratio. The ring finger length exhibits a better sexing potential followed by index finger length. Although there is no rule of thumb, sexing methods that show less than 80–85% accuracy are often deemed unreliable by forensic anthropologists and rarely used. Both IFL and RFL estimate sex with a lower accuracy level and hence, the technique should be employed only in cases when no other means of sexing are available. The predictive accuracy however, increases when IFL and RFL are taken together. The study suggests that the index and ring finger ratio should not be employed in estimation of sex in forensic casework due to considerable overlap in male–female values. The results of the study are applicable only to adolescent populations and should not be employed on adult groups. In the case of still growing individuals, it is probably more useful to estimate age than sex and stature. Once it is established that the remains belong to a growing individual (non-fusion of the epiphyses of phalanges in cases of dismembered hand and fingers), the findings of the study can be applied to estimate sex. Estimation of sex can thus help in the process of identification directly by narrowing down the pool of possible victim matches as well as by aiding in a more accurate estimation of age based on the predicted sex since the age of epiphyseal fusion varies between males and females. Studies on estimation of sex in sub-adult cases need to be encouraged. Future studies on estimation of sex from finger lengths in adult populations are proposed. Since the present study has been conducted on the sub-adult Rajput population, the results are applicable to this population only. However, the results of the study open new avenues for similar kind of research where similar studies are conducted on other populations with large sample size and this data can be used for comparison purposes.

Ethical approval

None declared.

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Department of Anthropology Panjab University, Chandigarh, India.

Conflict of interest

None declared.

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